OPERATIONAL EVALUATION OF LOW LEVEL WHITE LIGHTING

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OPERATIONAL EVALUATION OF LOW LEVEL WHITE LIGHTING

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SUMMARY

An evaluation of Low Level White (LLW) lighting was conducted at sea on board a fast attack submarine. Three watch sections performed their normal duties for two six hour periods under LLW and red ambient illumination. Subjects rated the ease of performing job related tasks under both lighting conditions. The LLW lighting was rated significantly higher than red lighting. LLW lighting provided many advantages over red lighting such as less eye strain, less fatigue, fewer headaches and enhanced CRT performance. Recommendations are made for the future use of LLW as the standard for night time ambient illumination.

INTRODUCTION

Watchstanders on U.S. submarines have voiced many complaints over the requirement to use red light for night time ambient illumination. They complain about headaches, feeling generally fatigued, difficulties in reading, and an inability to discriminate color coded information. As a result, the continued use of red lighting has been questioned (NSMRL ltr 18Nov70).

The Naval Submarine Medical Research Laboratory (NSMRL) has conducted a series of studies over the last three years to evaluate the feasibility of replacing red lighting onboard U.S. submarines with low level white (LLW) lighting. These studies have compared the effects of LLW or red ambient lighting on dark adaptation (Luria and Kobus, 1984; 1985), and evaluated performance in operational trainers (Luria and Kobus, 1983). In addition, performance in the sonar room (Kobus and Luria, 1985) and in the control room (Luria and Kobus, 1985) has been monitored at sea. A review of these studies has recently been published (Luria, Kobus, and Neri, 1986).

The present study is another in the series of at-sea evaluations of LLW lighting as a replacement for red lighting. In this study we were concerned with exploring operational differences in periscope viewing between the two lighting conditions during simulated emergency conditions, as well as with evaluating various lighting modifications in transitional areas.

Recently, SUBPAC has voiced concern regarding the effect of LLW light on periscope vision during emergency procedures. During an emergency, there may not be time to rig the compartment for black (no light) long enough to allow the observer to completely dark adapt before coming to periscope depth. Therefore, an operational evaluation of periscope use with experienced observers was requested.

In addition, a second problem arose when white light was substituted for red light in compartments and passageways adjoining the control room. Kinney (1981) has shown that the luminances of different colors cannot be measured accurately with a photometer at low intensities. She provided a nomogram with which to obtain a more accurate brightness match at low levels of ambient lights of different colors. Luria and Kobus (1983) used the nomogram to choose the neutral density (ND) of a filter that would match the brightness of blue or white light to that of the red lighting used on submarines. When these filters were used, however, they found that the light in the peripheral areas such as passageways, appeared too bright when viewed out of the corner of the eye and were distracting (Luria and Kobus, 1985). This problem was corrected by adding an additional 0.8 ND (total ND=2.1) to the passageway filters.

In a subsequent study, however, several observers complained that the control room filters were too bright. In the present study, an attempt was made to solve both problems by using filters of intermediate density-- that is, brighter than the original control room filters but dimmer than that used in the peripheral areas-- everywhere. If acceptable, there would not be different filters in the passageways and in the control room. This would eliminate the need to manufacture filters of more than one density.

METHOD

Experimental Conditions - All participants were exposed to both red lighting and LLW lighting for an entire six hour watchstanding period, and all completed a rating questionnaire at the end of each watch.

Light Levels - In this study, the brightness of the LLW was not equated to that of the red light. Rather, it was made 0.4 ND dimmer, and the same light levels were used in all compartments and passageways.

Procedure - The procedures followed were identical to that of Luria and Kobus (1985). The watchstanders were grouped into three sections; each was on duty for six hours. Each section evaluated the illuminants in a different order. Two sections evaluated LLW first, and the third section evaluated the red light first. Questionnaires were tailored to each watch station. Questions are listed in Appendix 1 (Note: All questions did not appear on any single questionnaire). All were designed to evaluate how well the normal watchstanding duties could be performed under each illumination. The watchstanders were asked to rate the illumination on a scale of 1 to 10 for the ease with which it permitted tasks that were required of their specific watchstation. The final question, rating the overall quality of the illumination, appeared on all questionnaires.

Periscope Test - Visual performance under the LLW and the red lighting systems was compared under simulated emergency conditions. This procedure was evaluated only for the periscope operator and was simulated by rigging the control room for LLW and having the periscope operator look into the scope without any time to dark adapt.

The task of the subject was to detect several known landmarks or visual aids after exposure for at least 30 minutes to LLW or red lighting. Ten highly experienced operators, including the commanding officer, the executive officer, the navigator, four OOD's, and three quartermasters served as subjects. To ensure the safety of the ship, this procedure was carried out at night while on the surface.

RESULTS

The responses to each of twenty-one questions comparing the red and LLW lighting for operational use were subjected to a one-way analysis of variance. The number of subjects in each analysis varied from 4 to 58 depending upon whether or not the question pertained to that particular watchstation.

The LLW light was rated better than red in every case. This was especially demonstrated by the subjects rating the overall quality of LLW lighting as significantly better than red lighting ($F(1,57)=47.41$, $p<.001$).

For 12 of the questions, the subject's rating were significantly higher when using LLW lighting (see Table 1). The use of LLW lighting was reported to result in significantly less eye fatigue ($F(1,55)=16.27$, $p<.001$) than when the subjects performed the same tasks under the red lighting. This result conforms to the significant advantages found for LLW lighting while reading publications ($F(1,57)=30.8$, $p<.001$), reading panel lettering ($F(1,57)=23.35$, $p<.001$), viewing CRT displays ($F(1,56)=8.10$, $p<.01$), and writing new log entries ($F(1,35)=17.63$, $p<.001$). Less eye fatigue may also be responsible for the significantly fewer number of headaches that were reported ($F(1,57)=4.10$, $p<.05$).

TABLE 1

QUESTIONNAIRE SUMMARY TABLE

MEAN RATING

PERFORMANCE AREA	LLW	RED	SIG.LEVEL
Publications	7.0	3.65	$p<.001$
Panel lettering	7.44	4.52	$p<.001$
Illuminated display	8.16	6.55	$p<.01$
Mobility	6.41	3.33	$p<.001$
Eye fatigue	6.25	3.81	$p<.001$
Headache[1]	.05	.23	$p<.05$
Afterwatch activity[2]	.43	.12	$p<.05$
Log entries	7.08	3.79	$p<.001$
Colored plots	8.00	1.75	$p<.001$
Updating charts	8.50	2.33	$p<.01$
Maintaining equip.	6.36	1.67	$p<.01$
Overall quality	7.89	3.86	$p<.001$

[1] Response to this question was yes or no. Analysis was done by having yes=1 and no=0. Therefore, lower values indicated fewer headaches.

[2] Response to this question was yes or no. Analysis was done by having yes=1 and no=0. Therefore, lower values indicated less desire to have after watch activity.

In addition, LLW provided a significant advantage over red lighting in discriminating color coded information ($F(1,23)=85.52$, $p<.001$). A significant advantage also was found while using LLW lighting when mobility was required ($\underline{F}(1,54)=20.94$, $\underline{p}<.001$). The subjects also reported that they were more likely to stay awake to work on other tasks after their LLW watch than after the watch section that used red lighting ($\underline{F}(1,38)=5.04$, $\underline{p}<.05$).

Statistically significant differences were not found between lighting conditions for ten of the analyses (see Appendix 1 Table A). It should be noted, however, that data for these questions were collected on fewer than five subjects making the data difficult to interpret. Selected comments are given in Appendix 2.

Periscope Test - Although the night was overcast, all 'targets' were quickly detected under both lighting conditions. All observers reported that they did not notice any differences in their performance between the LLW and the red lighting systems. Yet, they preferred the LLW system due to the advantages it offered away from the periscope.

DISCUSSION

The use of LLW lighting provided many significant advantages over red lighting including less eye strain, less fatigue, fewer headaches, increased ease of movement about the compartment, and enhanced CRT performance. The use of higher density filters in all compartments was found to be completely acceptable to the crew. It provided uniform lighting and reduced the transitional problems between the control room and adjoining spaces. It also apparently reduced the time differences found between red and LLW filters for total dark adaptation, since visual performance during the periscope test was the same for both lighting conditions.

In short, the use of the LLW lighting system, with 1.6 log ND filters, in most cases is better for performing various tasks in the control room, than red lighting. The operational forces have considered all the advantages that the LLW filter provides and have requested that the filters be installed on a permanant basis (USS Whale ltr 18Nov84; USS William H. Bates ltr 15Apr86). This study supports the research carried out by NSMRL and leads to the recommendation that the LLW filters be permanently installed in the sonar and control room areas on all U.S. Submarines.

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9. Co, USS Whale (SSN 638) ltr, 9330, Ser 51/434 to Co, NSMRL of 18Nov84.

APPENDIX 1

Table A lists all the questions used. Each questionnaire was designed to specifically evaluate aspects of performance for a particular watchstation. No single questionnaire contained all questions. Therefore, the N varied between questions. For several of the analyses the N was quite small (N<5) and therefore the results could not be interpreted. The superscripts denote if the results were statistically significant (s) or not significant (ns).

TABLE A

1. Rate the difficulty of reading publications.[s]
2. Rate the difficulty of reading panel lettering.[s]
3. Rate the difficulty of reading illuminated display panels.[s]
4. If you had to go through other compartments (sonar, CCC, passageways), rate the difficulty or discomfort of the changes in brightness and time to readapt.[s]
5. Rate how tired your eyes got during the watch.[s]
6. Did you get a headache?[ns]
7. Do you feel like staying up and doing other things after this watch or do you feel you must go to sleep right away?[s]
8. Rate the quality, desirablility, effectiveness, etc., of this light.[s]
9. Rate the difficulty of operating the BCP without the use of a flashlight.[ns]
10. Rate the difficulty of operating the BCP during a periscope depth approach.[ns]
11. Rate the difficulty of making log entries.[s]
12. Rate the difficulty of reading colored plots.[s]
13. Rate the difficulty of using the periscope.[ns]
14. Rate the difficulty of updating charts.[s]
15. Rate the difficulty of viewing the BCP/SCP from the conn.[ns]
16. Rate the difficulty of viewing fire control crts?[ns]
17. Rate the difficulty of using sonar repeaters.[ns]
18. Rate the difficulty of maintaining equipment.[s]
19. Rate the difficulty of viewing a CRT.[ns]
20. Rate the difficulty of color coding valves.[ns]
21. Rate the difficulty of doing rounds without a flashlight.[ns]
22. Additional comments.

[s] denotes a statistically significant difference - significance levels are shown in Table 1.

APPENDIX 2

The comments listed below were selected from the reports given by the subjects:

1. Red seems to increase the frequency of tension headaches.(COW)
2. Red is an excitable color.(FT)
3. (Using LLW lighting) it is very easy to adapt from bright to dim.(IC FWD)
4. (LLW) makes me more alert than red light.(SCP)
5. Less discomfort, less stress, less strain, which make it much easier.(SCP)
6. ... colors are easy to differentiate.(OOD)
7. ... allows better access to control room spaces and allows better views of panels.(OOD)
8. ... CRT display are read much easier with less glare.(FT)

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Three submarine watchsections performed their normal duties at sea for two six periods under Low Level White (LLW) and red ambient illumination. At the end of each watch, subjects evaluated the light and rated the ease of performing various tasks at their watchstation. LLW lighting provided many advantages over red lighting, including less eye strain, less fatigue, fewer headaches, increased ease of movement about the compartment, and enhanced CRT performance. Overall, LLW was the preferred ambient illumination. Recommendations are made for the future use of LLW as the standard for night-time ambient illumination.

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